REMARKS

Claims 208 and 217 are amended; claims 221-233 are withdrawn; claims 234, 236, 237 and 239 are canceled; and claims 240-247 are added as new claims. Support is found, for example, on page 18, line 24 to page 19, line 25, and Figure 2. Hence no new matter is presented. Accordingly, upon entry of the Amendment, claims 208-233, 235, 238, and 240-247 will be all of the claims pending before the Examiner for examination.

Claims 208-213, 217-220, 235-236 and 238-239 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Tanaka et al (WO 97/11518) in view of Takeuchi et al (U.S. 5,239,188) and Ohba et al (U.S. 5,656,832).

Claims 214 and 216 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Tanaka in view of Takeuchi et al and Ohba et al and further in view of Tischler et al.

Claims 234 and 237 are rejected under 35 U.S.C. § 1039a) as allegedly being unpatentable over Tanaka in view of Takeuchi et al and Ohba et al and further in view of Harunori et al (JP 07-201745).

Applicants respectfully submit that the cited references do not teach or suggest the presently claimed invention as recited in independent claims 208 and 217 for the following reasons.

Independent claims 208 and 217 are amended herein to recite that the off-angled major surface of the dissimilar substrate has an off-angle which is less than 1° with respect to the major surface of the dissimilar substrate and that the off-angled major surface is formed stepwise such that the substrate has substantially horizontal terrace portions and stepped portions.

None of the cited references teaches or suggest an off-angled major surface being formed stepwise such that the substrate has substantially horizontal terrace portions and stepped portions as recited in independent claims 208 and 217. For this element of the claims the Examiner primarily relies on the disclosure of Harunori et al in stating, "Harunori et al discloses (see abstract) using a stepwise formation of a (0001) a.k.a. the C plane as a growth surface for GaN epitaxy. It would have been obvious to one of ordinary skill in the art at the time of the present invention to use a step wise off-angled substrate because such were known in the art to improve purity and crystallinity in epitaxy methods."

However, Applicants submit that Harunori's step shown in the selected drawing is quite different from that of the present invention as recited in amended claim 208 and as illustrated in Figure 2 of the present application, in which the off-angled major surface of the dissimilar substrate 11 has an off angle Θ less than 1° with respect to the horizontal plane and the off-angled major surface is formed stepwise such that the substrate has substantially horizontal terrace portions A and stepped portions B.

Secondly, although the abstract for the Harunori reference states the purpose of the invention of Harunori as "[T]o notably improve the purity and crystallizability of GaN epitaxial crystal . . .", the original Japanese laid-open publication, states that Harunori's actual objective is specifically to reduce <u>crystal defect or lattice defect</u> of the as-grown <u>GaN epitaxial crystal</u> on the sapphire. See the attached machine translation by JPO web site, e.g., [0021]. Applicants note that crystal defects are microscopic problems such as vacancy of nitride in gallium crystal, while the development of cracks is a physical or mechanical problem. These are basically separate and distinct issues to be considered in a semiconductor growth method.

In other words, Harunori focuses on the as-grown GaN epitaxial crystal itself on the sapphire, and not on further growth of nitride semiconductor layers on such GaN epitaxial crystal. To improve the quality of overgrown nitride semiconductor layers, the development of cracks is the key issue. In other words, if an underlayer had cracks inside, then the overlayer would continuously form cracks from the underlayer. However, Harunori cannot reduce cracks formed in the GaN epitaxial crystal itself on the sapphire, because if an overlayer is grown on the GaN epitaxial crystal as taught by Harunori, then such an overlayer would also develop cracks. Therefore, since Harunori cannot solve the problem which the present invention solves, one of ordinary skill in the art would not have been motivated to combine the references with a reasonable expectation of achieving the claimed invention as recited in amended claims 208 and 217.

Thirdly, Harunori teaches an off-angle of 2°-10° as the preferred range in claim 5 and [0019], which teaches away from the present invention, wherein the off-angle is 1° or less. Thus, even if the references were combined, the presently claimed invention would not have been achieved.

Accordingly, the present invention is not rendered obvious by the cited references, whether taken alone or in combination.

In view of the above, reconsideration and allowance of this application are now believed to be in order, and such actions are hereby solicited. If any points remain in issue which the Examiner feels may be best resolved through a personal or telephone interview, the Examiner is kindly requested to contact the undersigned at the telephone number listed below.

Amendment Under 37 C.F.R. § 1.116
U.S. App. Ser. No. 09/986,332

Atty. Dck. No. Q66212

The USPTO is directed and authorized to charge all required fees, except for the Issue Fee and the Publication Fee, to Deposit Account No. 19-4880. Please also credit any overpayments to said Deposit Account.

Respectfully submitted,

Jennifer M. Hayes
Registration No. 40,641

SUGHRUE MION, PLLC
Telephone: (202) 293-7060
Facsimile: (202) 293-7860
WASHINGTON OFFICE
23373
CUSTOMER NUMBER

Date: May 9, 2005 (timely filed, May 8, 2005, being a Sunday)

* NOTICES *

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1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention relates to the semi-conductor wafer in which nitride thin film crystals, such as Ga, aluminum, and In, were formed on the sapphire crystal substrate, and its manufacture approach.
[0002]
[Description of the Prior Art] Implementation of components, such as GaN and LED by the related compound, LD, and HEMT, is expected.
[0003] Epitaxial growth of GaN, AlN, and the InN is carried out on C-side of a sapphire single crystal, i.e., (0001), the field ground by the mirror plane of a field.
[0004] Epitaxial growth is mainly performed by vapor growth. especially -- organic metal vapor phase epitaxy (MOVPE) -- although many law is used -- chemistry vapor phase epitaxy (VPE) -- law and molecular beam epitaxy (MBE) -- law and the thing which used optical pumping and the plasma for these are also used.
[0005] By the MOVPE method, the epitaxial thin film of GaN is grown up by heating the above-mentioned sapphire single crystal substrate at about 1000 degrees C in hydrogen or nitrogen-gas-atmosphere mind, and passing the gas of trimethylgallium (TMG) and ammonia (NH_3).
[0006] In AlN or InN, trimethylaluminum (TMA) and trimethylindium (TMI) are respectively passed instead of TMG, and it grows.
[0007] Conventionally, the about [100-1000A] thin film of AlN or GaN is grown up at about 600-degree C low temperature on silicon on sapphire. By heating and heat-treating this at about 1000 degrees C, and growing up GaN at the temperature after that, it is reported that the quality of a GaN layer improves and the undoping GaN epitaxial crystal of n mold whose carrier concentration is about [4x1016 to 2x1017cm -] three is obtained (well-known examples 1 and 2).
[0008] Moreover, the p mold GaN epitaxial crystal of the carrier *concentration of 1(well-known example 4) x1017-6x1018cm-3 is*

obtained carrying out exposure processing of the GaN which added zinc (Zn) and magnesium (Mg) with an electron ray (well-known examples 1 and 3), and by annealing in inert gas.
[0009] Well-known example 1: (P51 - month, and "the electronic ingredient technique for high brightness blue luminescence, edited by Taguchi, and the December, 1991 [58 or] issue (Science forum company)")
Well-known example 2:S.NAKAMURA:J.J.A.P. -- VOL30, No(es)A [10] and 1991, and ppL1705-L1707 well-known example 3:S.NAKAMURA:J.J.A.P. -- VOL30, No(es) 10A and 1991, ppL1708-L1711 well-known-example 4:S.NAKAMURA:J.J.A.P.vol31, and pp(1992)1258-11266 Part1 and No.5A [0010]
[Problem(s) to be Solved by the Invention] Even if the GaN crystal which grew by the conventional approach mentioned above makes a low-temperature growth buffer layer intervene, purity and its crystallinity are still inadequate.
[0011] Moreover, although the high-concentration p mold GaN epitaxial crystal is experimentally obtained in part by heat treatment after electron beam irradiation or growth to the high-concentration n mold GaN (as for high concentration, carrier concentration saying three or more [1x1018cm -] here) epitaxial crystal being easily obtained by Si dope etc., by the time it is obtained easily, it will not be without such after treatment as ** in the state of the so-called AZUGUROUN (as grown).
[0012] When this invention person etc. had not examined the growth side of a substrate at all, changed the viewpoint and examined the growth side of a substrate wholeheartedly conventionally paying attention to the point of having improved quality by amelioration of an epitaxial grown method, and the after treatment of a growth crystal chiefly only using the field (0001) silicon on sapphire which does not incline, and the growth side was made to incline, he acquired the knowledge that large upgrading could be measured.
[0013] Therefore, by inclining a growth side, the purpose of this invention solves the trouble of the conventional technique mentioned above, and is to offer the semi-conductor wafer and its manufacture approach of of the GaN and the related compound (mixed crystal of AlN, InN, and these and GaN) whose high concentration p mold doping purity and crystallinity improve sharply and is attained.
[0014]
[Means for Solving the Problem] The substrate of the so-called fine inclined plane which leaned and carried out mirror polishing of the field (0001) of a sapphire single crystal substrate to predetermined ******** as a substrate to which epitaxial growth of the GaN etc. is carried out is used for this invention. The epitaxial crystal of the quality high

concentration p mold GaN and a related compound is realized by carrying out epitaxial growth of the GaN etc. on this fine inclination (0001) side.

[0015] That is, the laminating of the monolayer or the multilayer crystal of p mold of gallium nitride (GaN), alumimium nitride (AlN), indium nitrides (InN), or such mixed crystal, n mold, or i mold thin film is carried out on the fine inclination (0001) side of the sapphire crystal substrate which has the mirror plane where the semi-conductor wafer of this invention fine-inclined the field (0001) in the <21*1*0> direction or the <011*0> direction.

[0016] Moreover, on the fine inclination (0001) side of the sapphire crystal substrate which has the mirror plane which fine-inclined the field (0001) in the <21*1*0> direction or the <011*0> direction, a GaN buffer layer, a p mold GaN layer, and an n mold GaN layer carry out the laminating of the semi-conductor wafer of this invention one by one, and use it as the wafer for blue light emitting diodes.

[0017] Moreover, the manufacture approach of the semi-conductor wafer of this invention carries out mirror polishing of the field (0001) of a sapphire single crystal substrate, fine-inclined, and the monolayer of a wafer or the epitaxial layer of multilayer structure is made to grow on it.

[0018] Moreover, the manufacture approach of the semi-conductor wafer of this invention grows a buffer layer on a sapphire crystal substrate. In the manufacture approach of a semi-conductor wafer of having the process which grows a p mold GaN layer and an n mold GaN layer on it, and carries out vapor growth of the GaN epitaxial crystal of pn structure The sapphire crystal substrate which makes a mirror plane the field which fine-inclined the field (0001) in the <21*1*0> direction or the <011*0> direction is used for a sapphire crystal substrate.

[0019] As for whenever [fine tilt-angle], in the manufacture approach of these semi-conductors wafer and a semi-conductor wafer, it is desirable that it is 2 degrees - 10 degrees either.

[0020] It is a thing.

[0021]

[Function] Many the hole and other crystal defects from which nitrogen escaped exist in the GaN epitaxial crystal which grew on conventional field (0001) silicon on sapphire, and this is considered that the purity of Undoping GaN is one of the cause which is not good, and the causes that the p mold GaN is not obtained easily.

[0022] It is thought that these crystal defects are generated in the epitaxial growth of a crystal. That is, as GaN / sapphire system crystal, for the so-called heteroepitaxial growth from which physical properties, such as a lattice constant of silicon on sapphire and a GaN crystal, differ considerably, as shown in drawing 3 , the GaN epitaxial crystal 2 which

grows up to be the field (0001) 3 on the field (0001) sapphire single crystal substrate 1 tends to act as the island-like Motonari Mitsugi chief, and this is considered with making the aforementioned defect easy to generate.

[0023] On the other hand, if homoepitaxial, since [which grows on a substrate of the same kind like the GaAs epitaxial growth on a GaAs substrate] epitaxial growth mode serves as two dimensional crystal growth, a crystal defect is reduced very much.

[0024] By the way, although the low-temperature growth AlN buffer and low-temperature growth GaN buffer which were mentioned above are considered that there is effectiveness which promotes this two dimensional crystal growth, they are still inadequate. In order to realize two dimensional crystal growth, it is effective to make growth mode into step flow mode.

[0025] Since many steps 6 exist in the fine inclination (0001) side 5 at this point if the fine inclination (0001) side sapphire single crystal substrate 4 of this invention is used as shown in drawing 1 , step flow mode growth of the GaN epitaxial crystal 2 on the basis of this step edge is realized easily.

[0026] Therefore, good GaN and the good related compound crystal by two dimensional crystal growth can be obtained. Moreover, while a high-concentration p mold GaN epitaxial crystal can be obtained without after treatment, such as electron beam irradiation and heat treatment after growth, easily in the state of AZUGUROUN, the concentration of an n mold GaN epitaxial crystal can also be raised more.

[0027]

[Example] Hereafter, the semi-conductor wafer of this invention is explained to the fine inclined plane on a sapphire single crystal substrate about the example which carried out gaseous-phase formation of the nitride thin film crystals, such as aluminum and Ga.

[0028] The sapphire single crystal substrate which leaned 2 degrees of <example 1> (0001) sides in the <21*1*0> direction, and carried out mirror polishing was set on the graphite susceptor in the fission reactor of MOVPE equipment, high grade hydrogen was passed enough, and the inside of a furnace was purged.

[0029] Next, the susceptor was heated for hydrogen gas with the sink in the furnace, the substrate was heated at 1000 degrees C or more, and it held 10 minutes or more. Then, substrate temperature is made into 600 degrees C, and it is TMA and NH3. It passed in the furnace and 50nm grew the so-called AlN buffer layer of low-temperature growth.

[0030] And it is supply into the furnace of TMA A stop, hydrogen, and NH3 A substrate is heated at 1030 degrees C, passing, TMG is passed in a furnace after that, and it is 5 micrometers about GaN. It grew up.

When the electrical property of this undoping GaN epitaxial crystal was measured by the hall effect method, carrier concentration is about [5x1015cm -] three in n mold, and the large improvement in purity was accepted compared with the former.
[0031] In addition, the flow rates of the hydrogen at the time of growth, NH3, TMG, and TMA are 10 l/min, 5 l/min, 3 cc/min, and 0.8 cc/min respectively.
[0032] When the same epitaxial growth as an example 1 was evaluated using 5 degrees and the silicon on sapphire leaned 10 degrees in the <21*1*0> direction in the <example 2> (0001) side, the undoping GaN crystal of the same carrier concentration was obtained. As for carrier concentration, the inclination for whenever [tilt-angle] to become so small that it be large was seen.
[0033] When the same epitaxial growth as an example 1 was performed using the silicon on sapphire which leaned the <example 3> (0001) side with 2 degrees, and 5-degree10 " in the <011*0> direction, the same result as examples 1 and 2 was obtained.
[0034] 20nm grew the GaN buffer layer at 600 degrees C instead of the AlN buffer layer used in the <example 4> example 1, and other conditions grew the undoping GaN crystal on the completely same conditions as an example 1. The carrier concentration of an undoping GaN epitaxial crystal is about [1x1015cm -] three in n mold, and the crystal of a high grade was obtained from the example 1.
[0035] <Example 5> this example is an example of the pn junction GaN epitaxial crystal wafer for LED shown in <u>drawing 2</u> . (0001) the fine inclination (0001) side sapphire single crystal substrate 4 which makes a mirror plane the field which leaned 2 degrees of fields in the <21*1*0> direction -- using -- the GaN epitaxial crystals 7, 8, and 9 of pn structure -- MOVPE -- it grew up by law.
[0036] Hydrogen gas was heated for the substrate 4 with the sink at 1050 degrees C like the example 1, and surface defecation was performed. Next, substrate temperature is lowered to 500 degrees C, and it is hydrogen, and TMG and NH3. 25nm grew the growth GaN buffer layer 7 whenever [sink low-temperature]. Next, hydrogen and NH3 Substrate temperature is raised to 1030 degrees C with a sink, and it is hydrogen, and TMG and NH3. Bis-SHIKUROPENTA diethyl magnesium (CP2 Mg) is poured, and it is 2 micrometers about the p mold GaN layer 8. It grew up.
[0037] It is hydrogen, and TMG and NH3 succeedingly. It is 2 micrometers about a sink and the n mold GaN layer 9 in a disilane (Si two H6). It grew up. After that NH3 When the crystal was cooled with the sink and it became 600 degrees C - 800 degrees C about hydrogen, it is hydrogen and NH3. It stops passing and is a high grade N2 to instead of.

Gas was passed and it cooled to the room temperature.
[0038] Here, they are hydrogen, NH3, TMG, CP2 Mg, Si two H6, and N2. Each flow rates are 20 l/min, 5 l/min, 1 cc/min, 2 cc/min, 1x10-4 cc/min, and 20 l/min.
[0039] The far high p mold GaN layer of high carrier concentration in which 5x1019cm-3 and the p mold GaN layer 8 are 1x1019cm-3 in the state of AZUGUROUN with Si dope according [the n mold GaN layer 9] to a disilane, and the carrier concentration of the grown-up crystal both exceeds 1x1018cm-3, and the n mold GaN layer were obtained.
[0040] When carried out also about 2 degrees, 5 degrees, 10 degrees, and the leaned substrate in the substrate which leaned growth of the <example 6> example 5, and evaluation respectively with 5 degrees and 10 degrees in the <21*1*0> direction, or the <011*0> direction, the same result as an example 5 was obtained to them.
[0041] As a crystal which is example > besides < and which can grow on a fine inclination (0001) side sapphire single crystal substrate, there is a multilayer-structure epitaxial crystal containing InN(s), and these mixed crystal and these other than AlN or GaN.
[0042] Moreover, other vapor growth other than MOVPE, such as MBE and plasma CVD, can also be used for an epitaxial grown method.
[0043] Furthermore, it replaces with silicon on sapphire, and also in the epitaxial growth of the GaN and the related compound using silicon carbide (SiC), a silicon substrate, etc., growth of this invention on a fine inclined plane is possible, and can raise the quality of an epitaxial crystal.
[0044]
[Effect of the Invention]
(1) According to the semi-conductor wafer according to claim 1, little quality GaN and quality related compound epitaxial crystal of a crystal defect are realizable.
[0045] (2) According to the semi-conductor wafer according to claim 2, the blue light emitting diode of high brightness can be made.
[0046] (3) According to the manufacture approach of a semi-conductor wafer according to claim 3, a quality semi-conductor epitaxial layer with few crystal defects can be formed on silicon on sapphire.
[0047] (4) According to the manufacture approach of a semi-conductor wafer according to claim 4, the high-concentration p mold GaN in the condition of AZUGUROUN is easily realizable.
[0048] (5) According to invention according to claim 5, since the fine tilt angle was specified to the optimal value, fewer quality GaN and the fewer quality related compound epitaxial crystal of a crystal defect are realizable.